Acid Doped Membranes for High Temperature PEMFC

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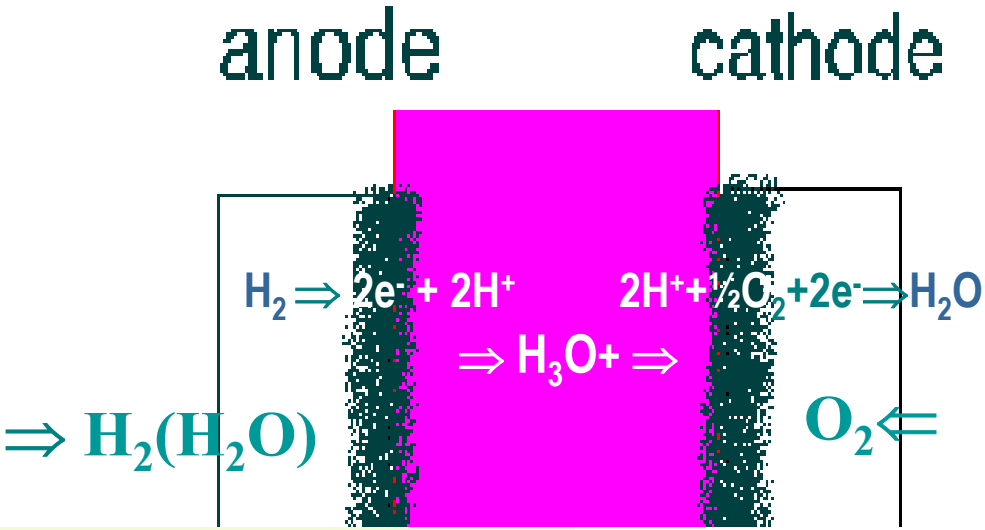
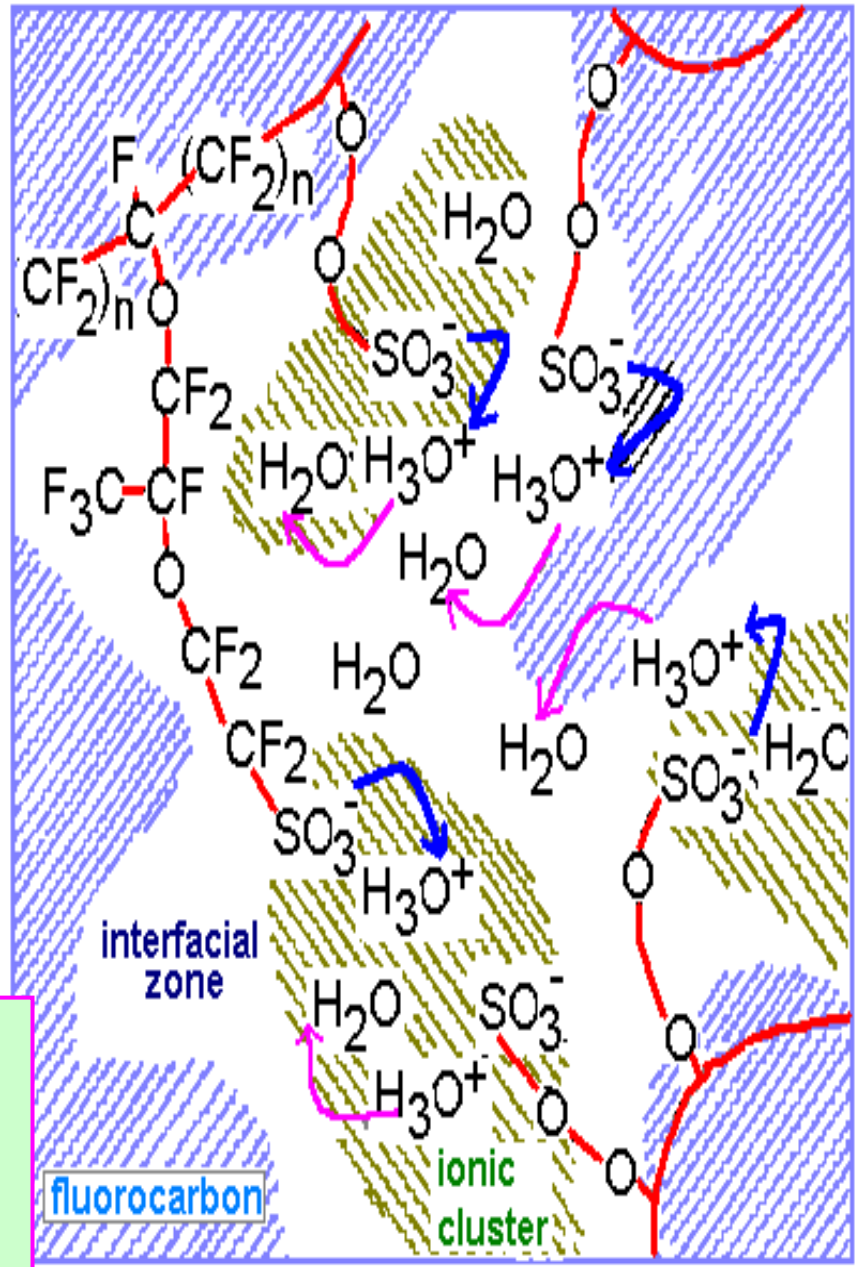
Perfluorinated sulfonic acid membranes (PFSA)

- Water-dependence of conductivity
- Water ballance between fluorocarbon and acid groups
- Electro-osmotic drag of water





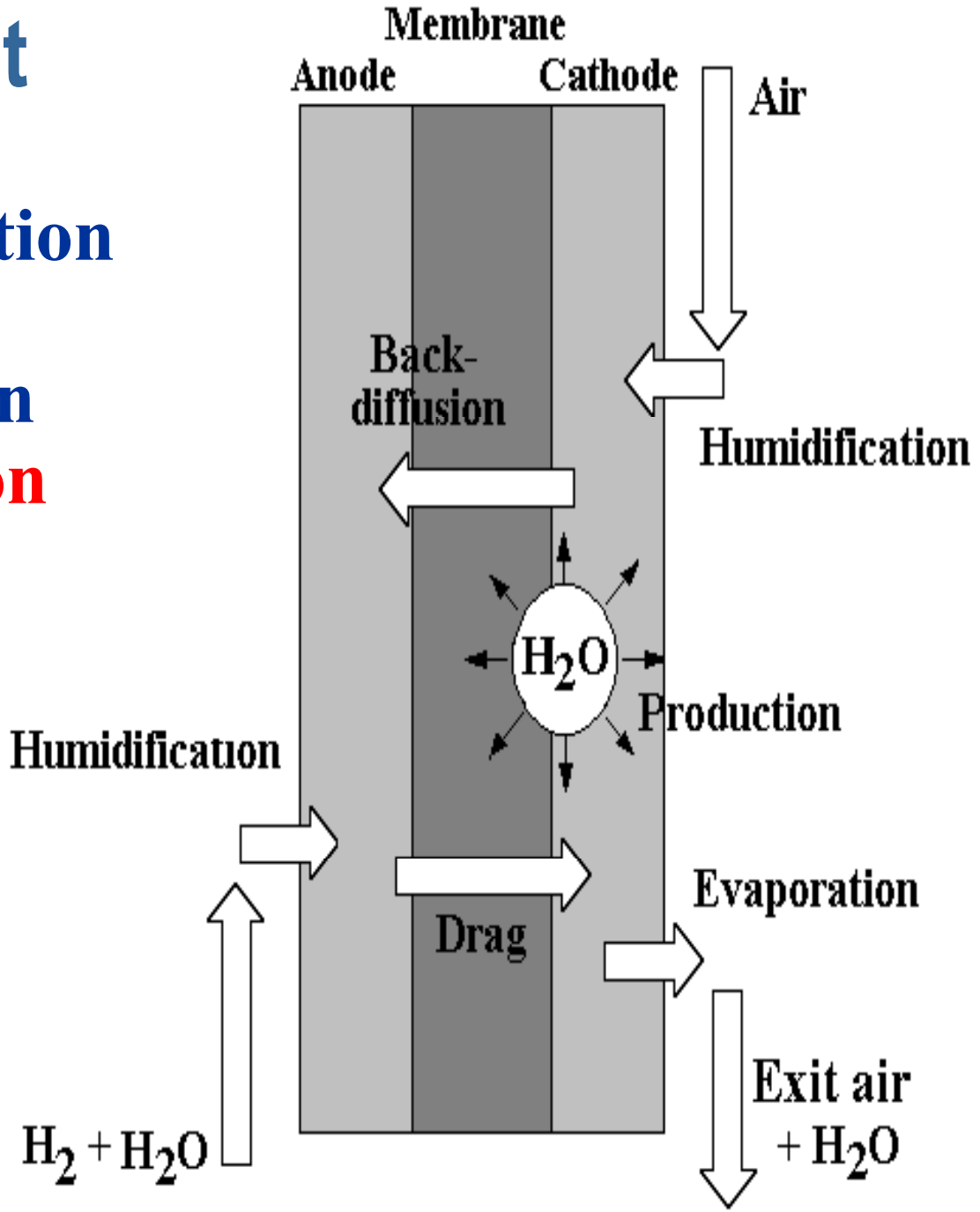
As a result:

⇒ Intensive humidification

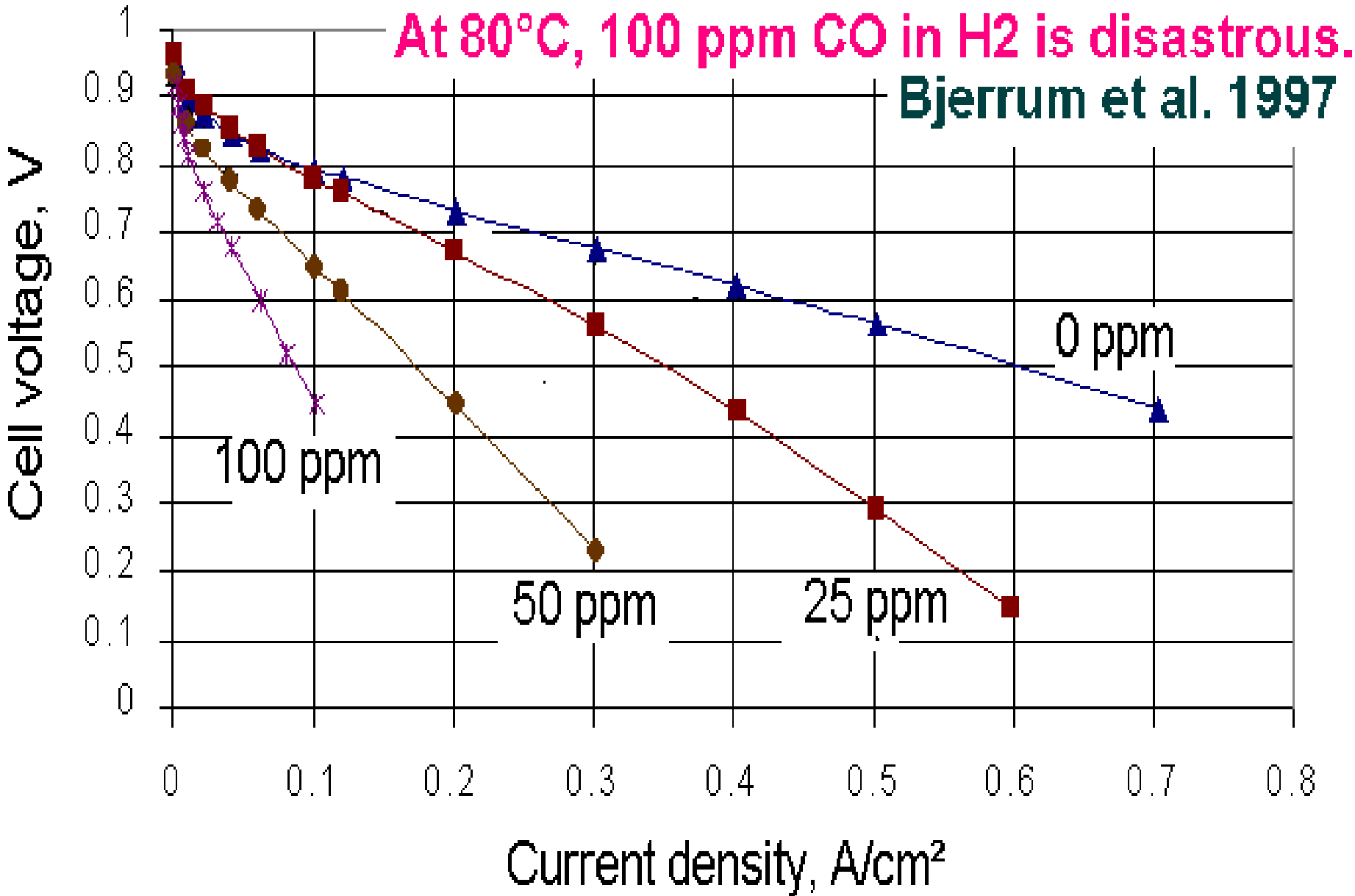
Water management

- Water drag
- Cathodic production
- Back diffusion
- Fuel humidication
- Air humidification

Water removed by evaporation into air
- stack temperature
- air flowrate (λ)
- inlet humidity
- outlet humidity
- pressure



Temperature dependence of CO poisoning



Higher operational temperature……

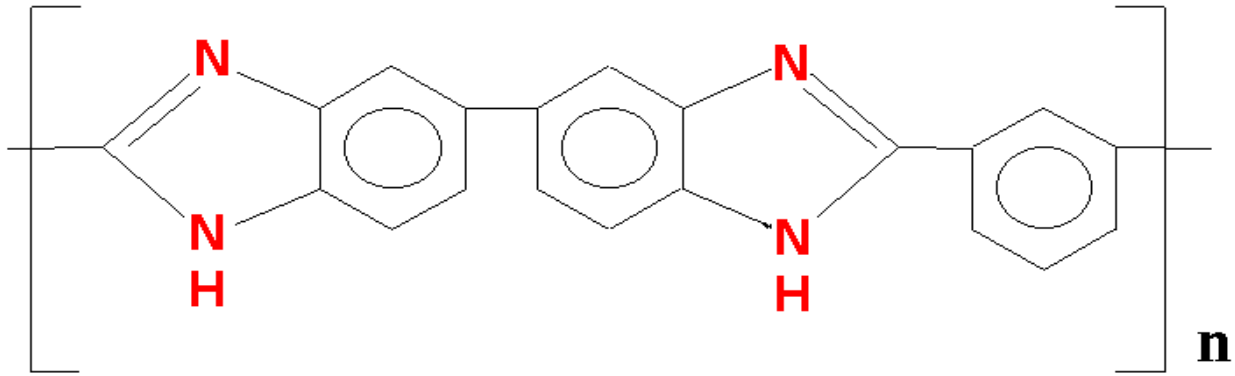
- **Increased catalytic activity**
  - ⇒ Fast electrode kinetics (O_2 reduction and methanol oxidation)
- **High tolerance to fuel impurities**
  - ⇒ Simplified reformer-purification system (reduced cost, weight, volume, startup / response time…)
- **Avoid two-water-phase operation**
  - ⇒ Simplified stack construction / operation (water management)
- **Easy thermal management**
  - ⇒ Effective cooling due to temperature gradient
- **Increased value of heat recovery**
  - ⇒ for steam reforming/H_2 desorption from metal hydride tank

High Temperature Polymers

Polybenzimidazoles

(Poly (2,2´-m-(phenylene)-5,5´´-bibenzimidazole (PBI)

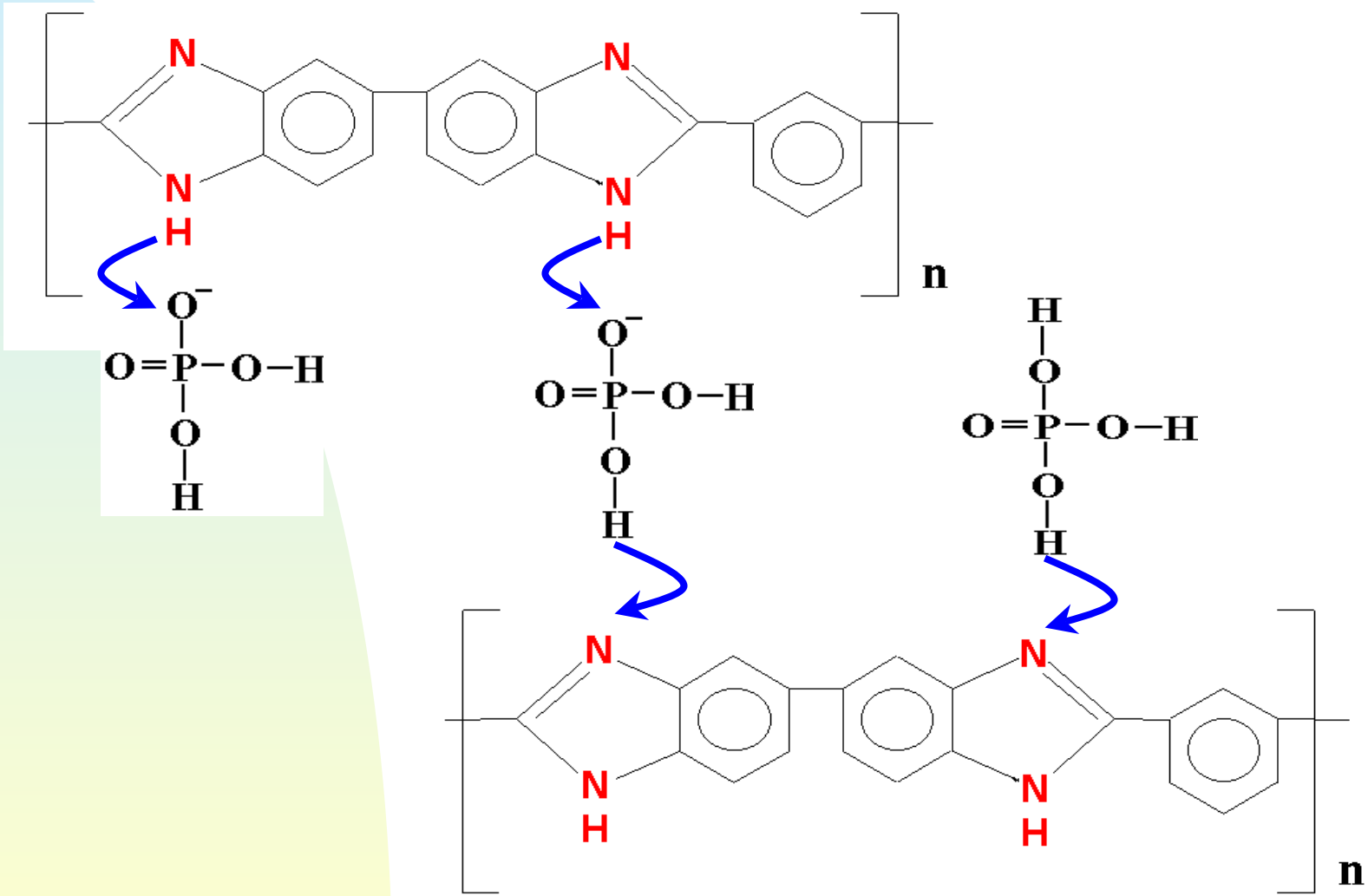
T_G = 425-435°C



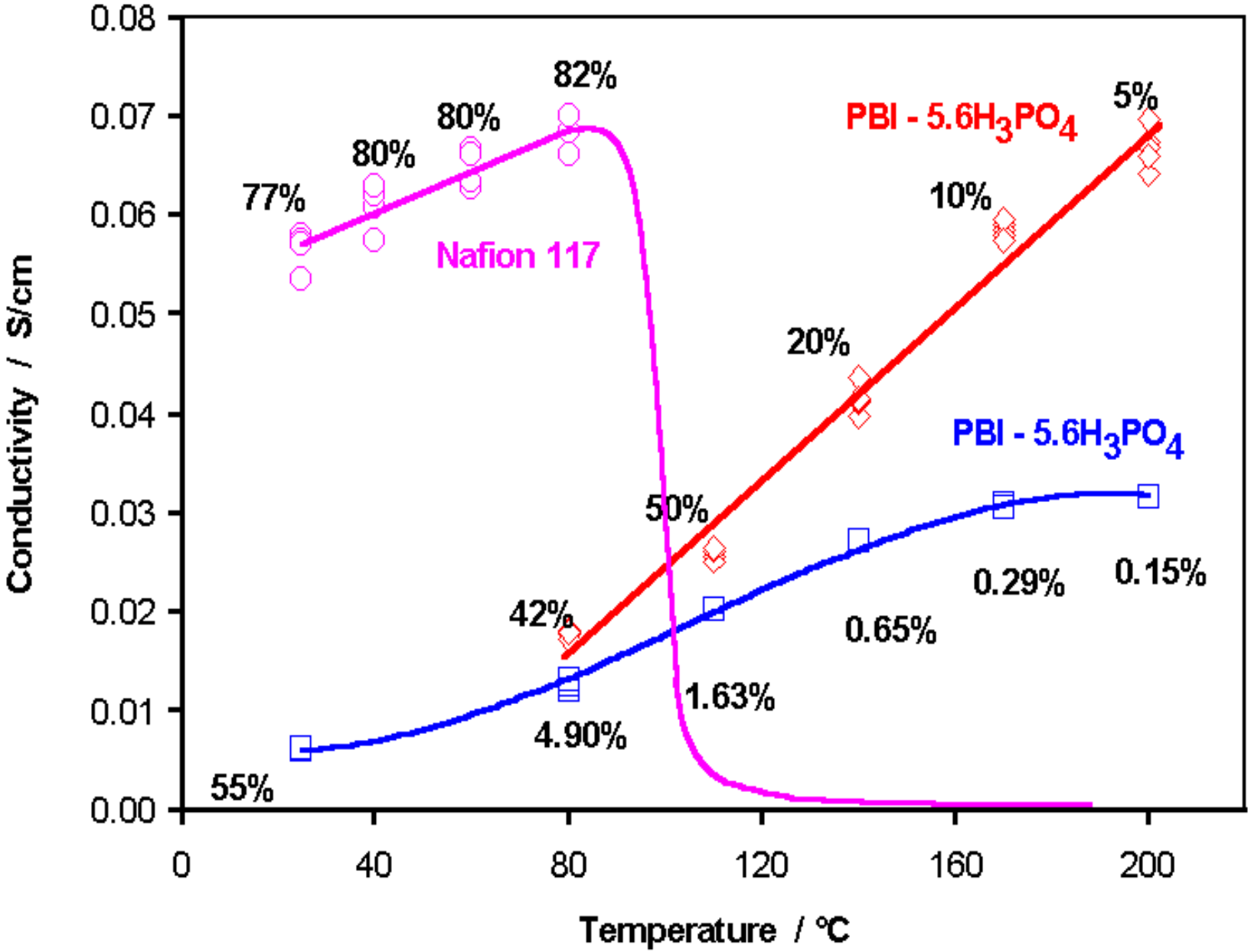
Applications

- As seals, insulator,
- As fibers for protective garments to astronauts, race-car drivers, fire-men ...
- As films & membranes for reverse osmosis and ultra-filtration ...
- Becoming conductive when …doped with acids (Savinell et al, 1995)

When doped with an acid



Conductivity of PBI/H_3PO_4 membrane

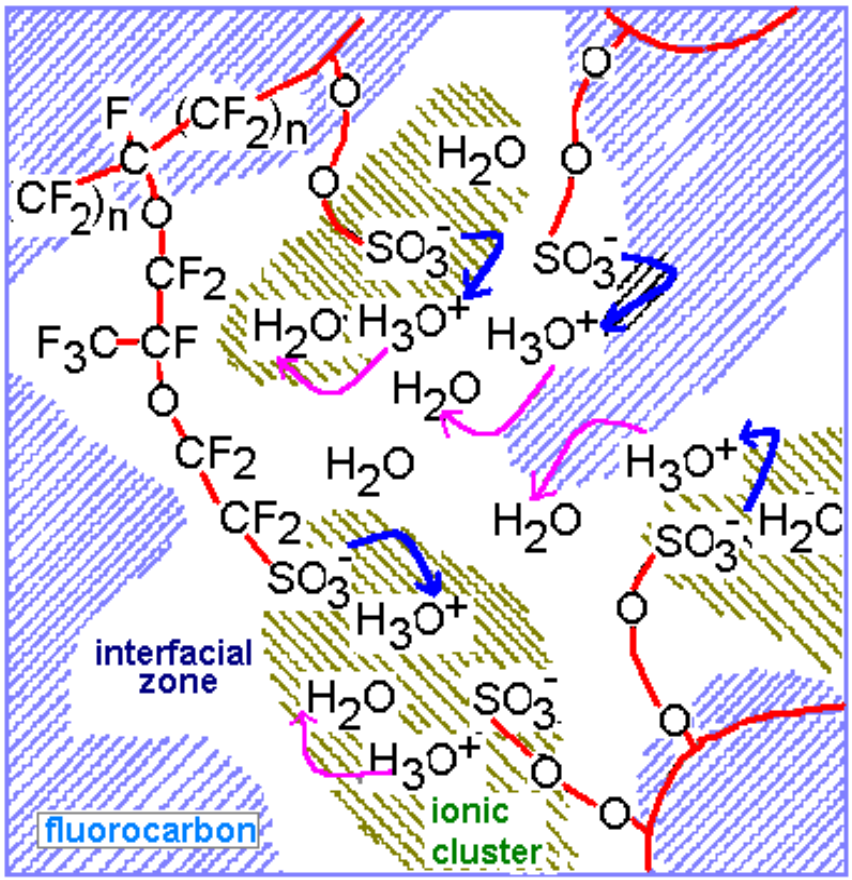


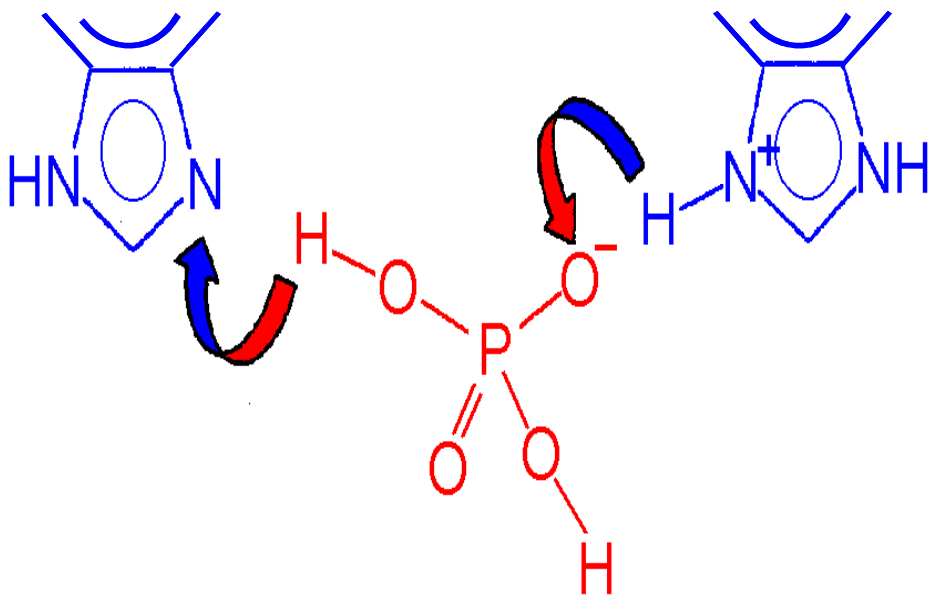
Water-osmotic Drag Coefficient

The molecular number of water dragged by each proton

- **Nafion/H_2O:**
  - 30°C, ≈1.4 (Fuller et al., 1992)
  - 1-3, (Zawodzinski et al., 1993)
  - 80°C, ≈ 3 (Bjerrum et al., 1998)

- **Nafion/H_3PO_4:**
  - 125-185°C, 0.2-0.6 (Weng et al., 1996)
- **PBI/H_3PO_4:**
  - 150°C, <0.03 (Weng et al., 1996)
  - ≈ 0 (Bjerrum et al., 1998)

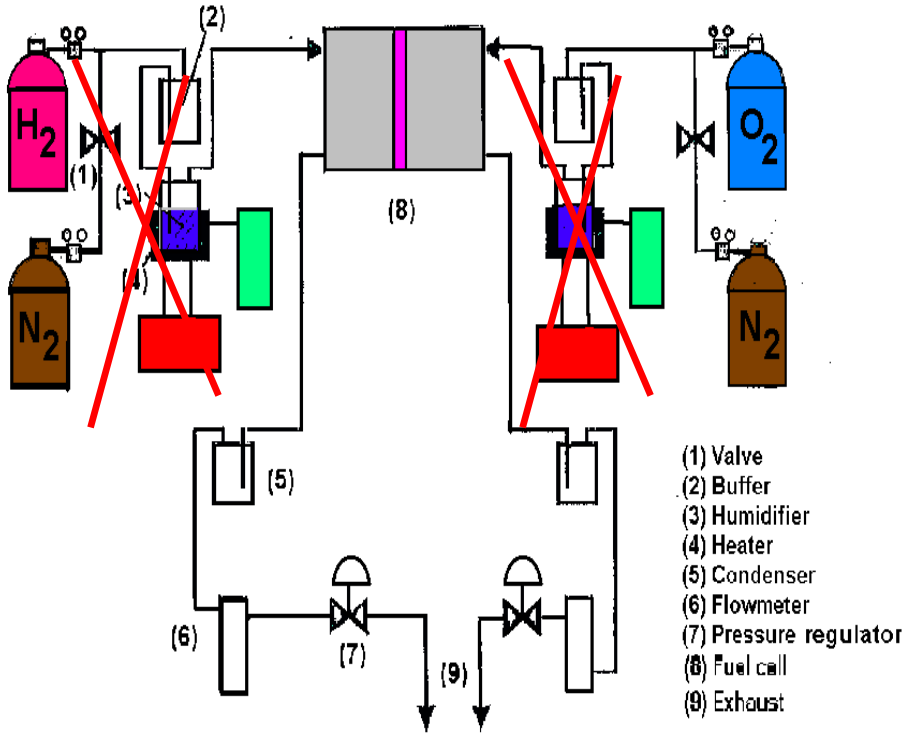


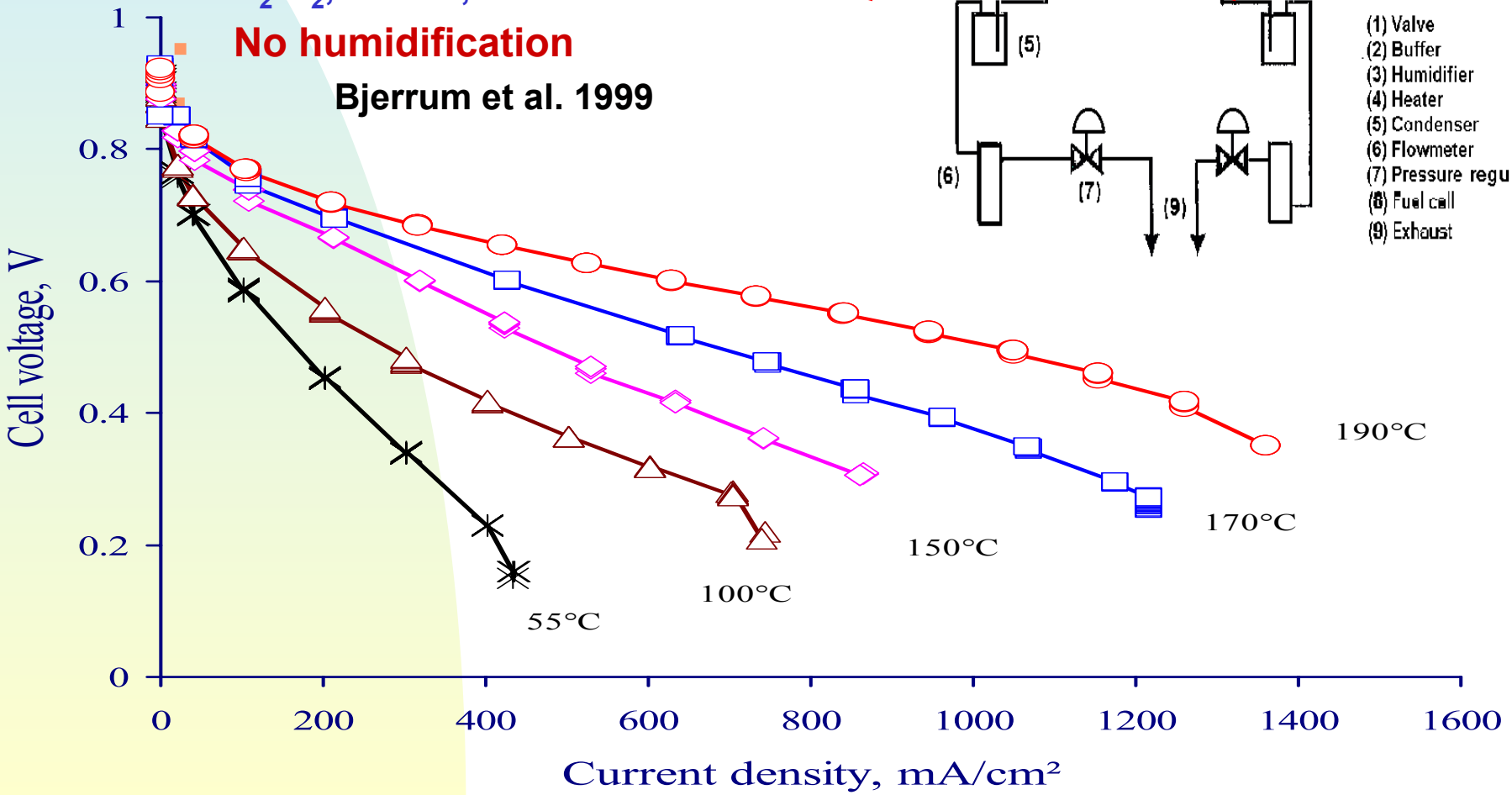


Performance
- different temperatures

- Electrode, 0.45mgPt/cm²
- PBI/H_3PO_4 membrane
- H_2/O_2, 1/1 bar, 150/150 ml/min
- No humidification

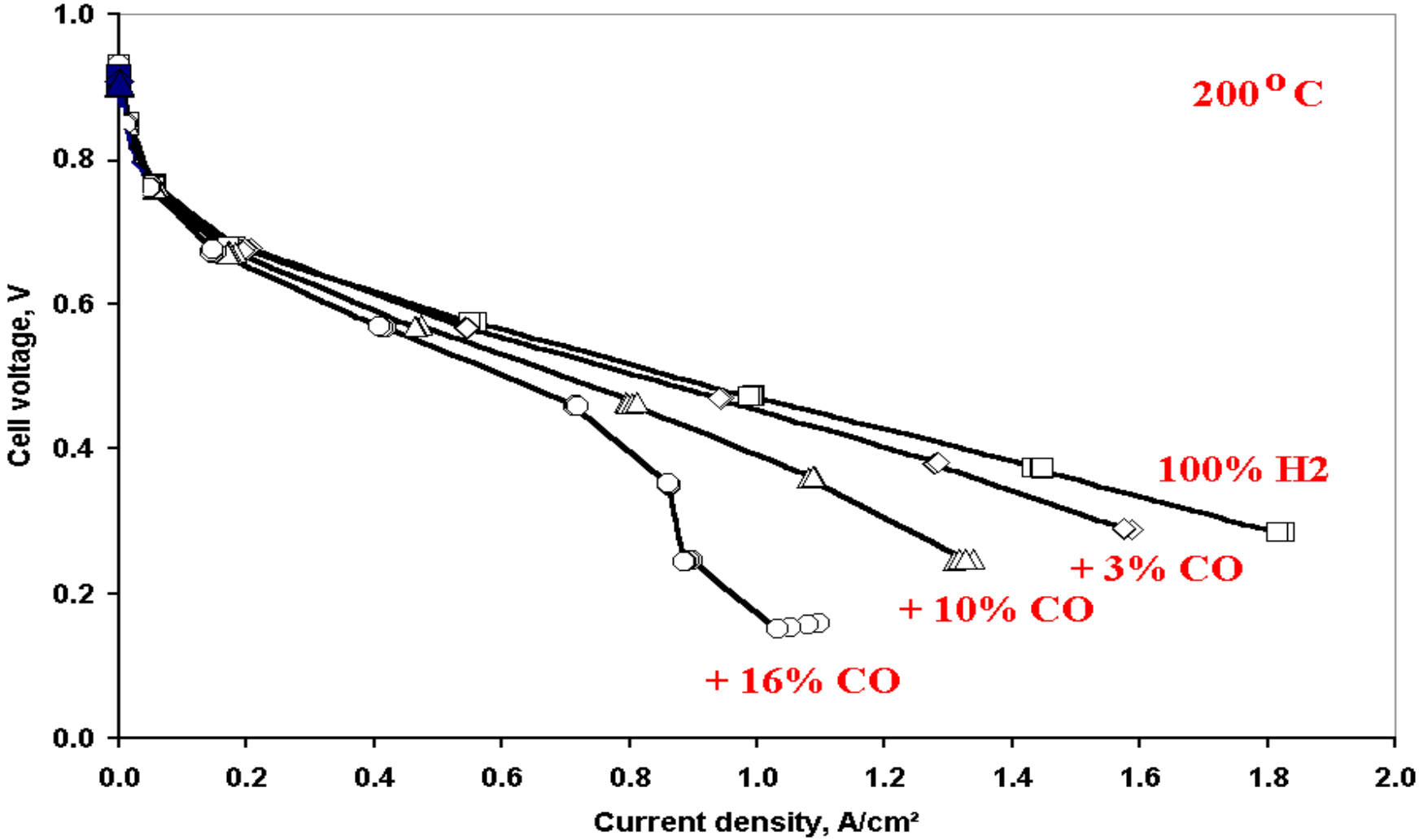
Bjerrum et al. 1999



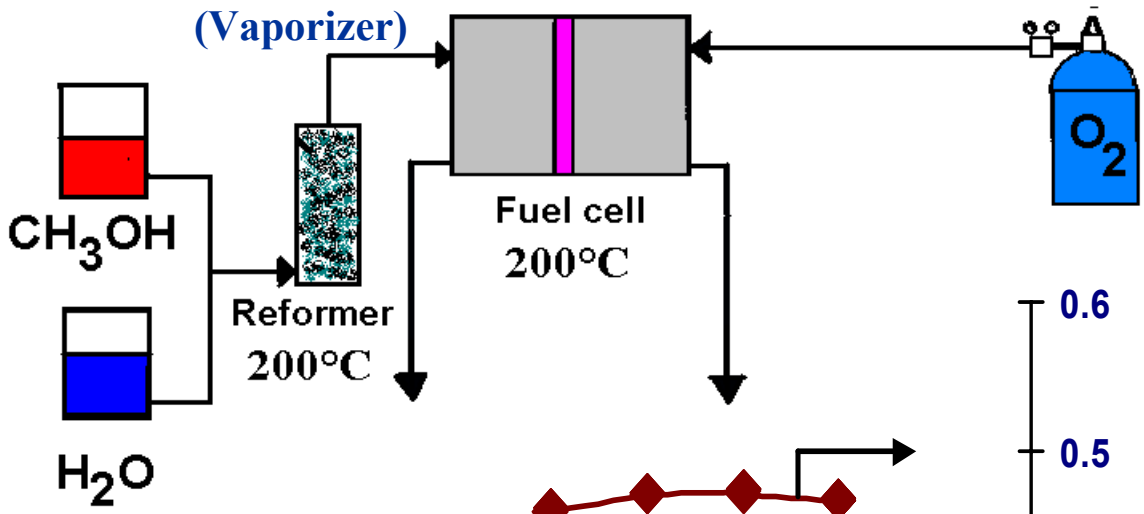


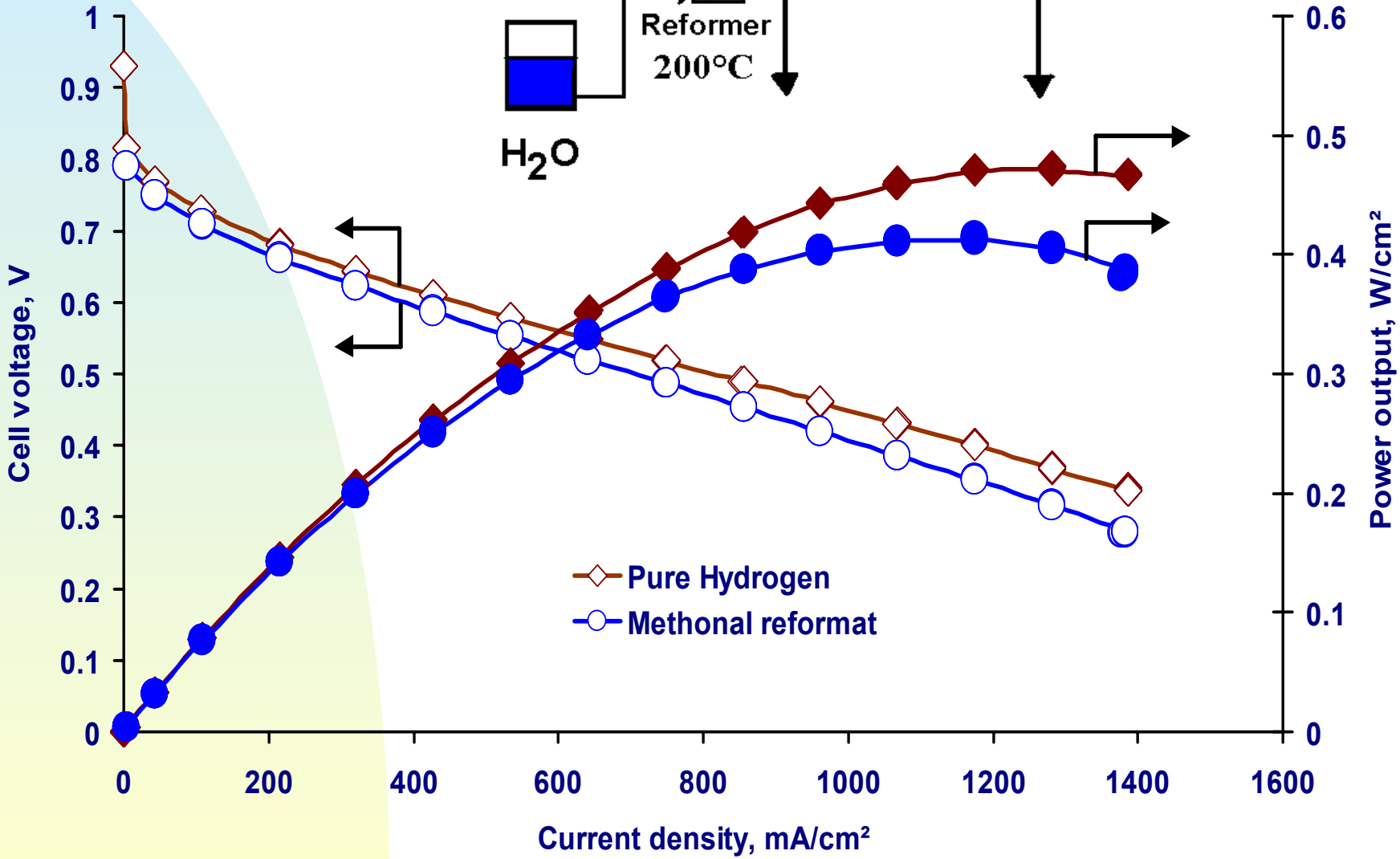
CO Poisoning
at high temperatures

At 80°C: Pt/C: 10 ppm CO
Pt-Ru/C: 100 ppm CO
At 200°C: Pt/C: 30,000 ppm CO

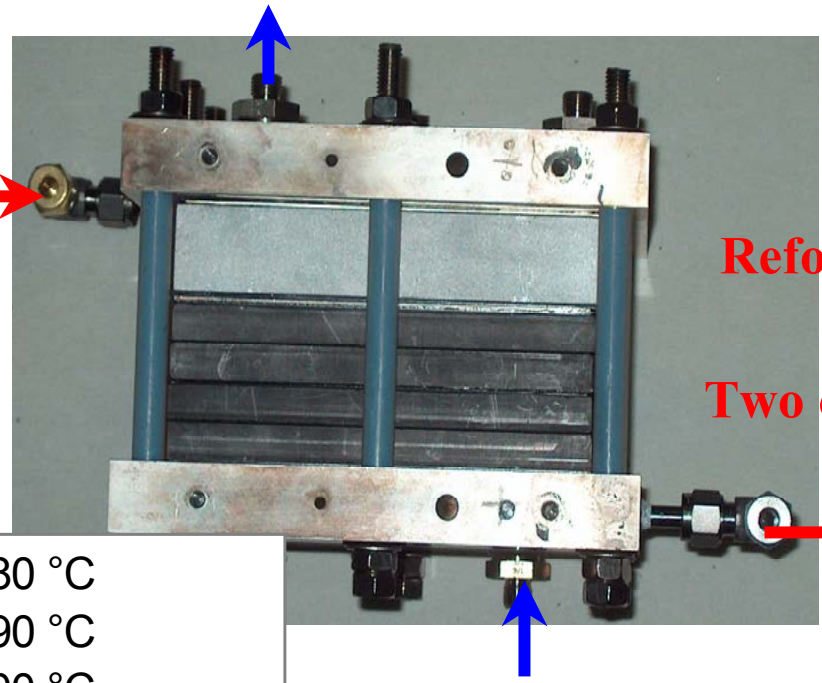


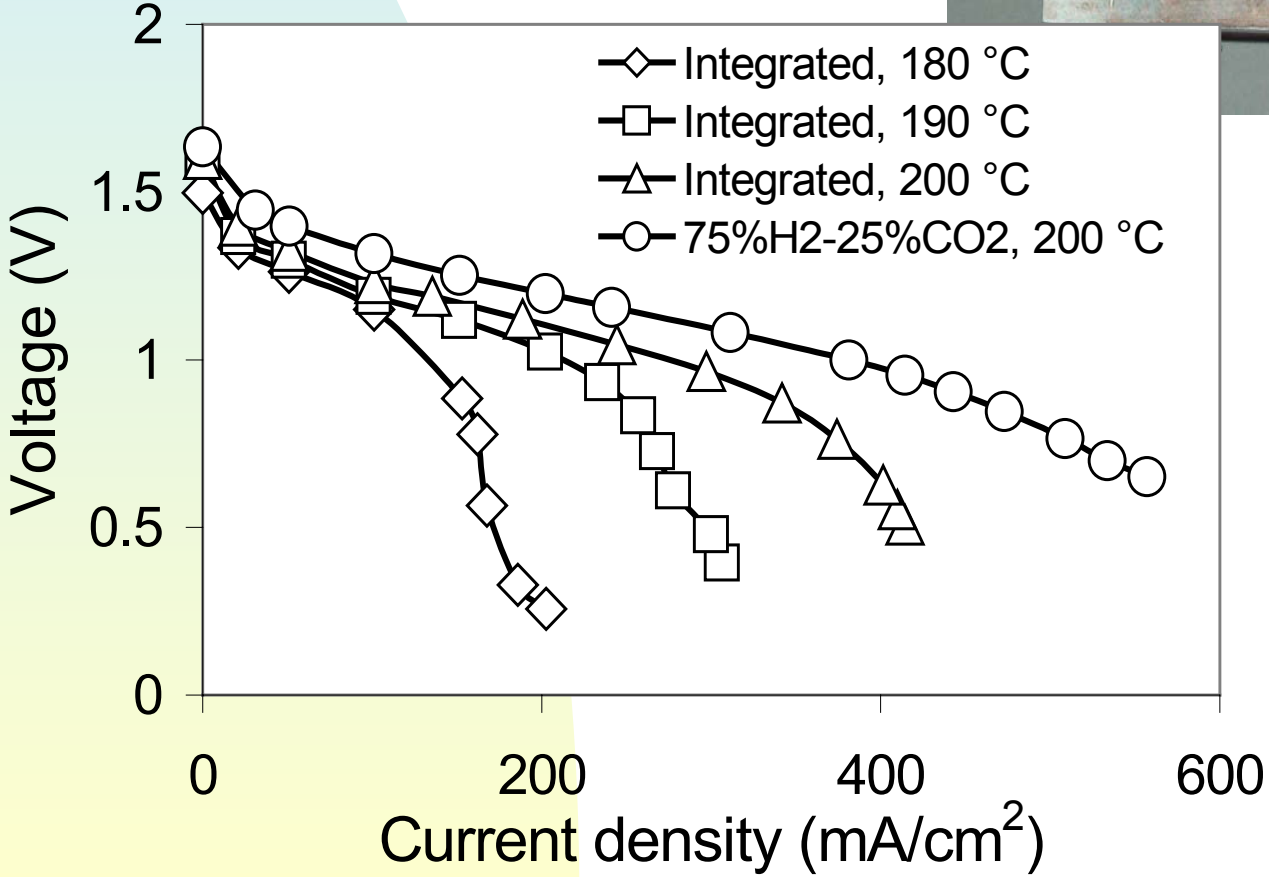
Possible integration

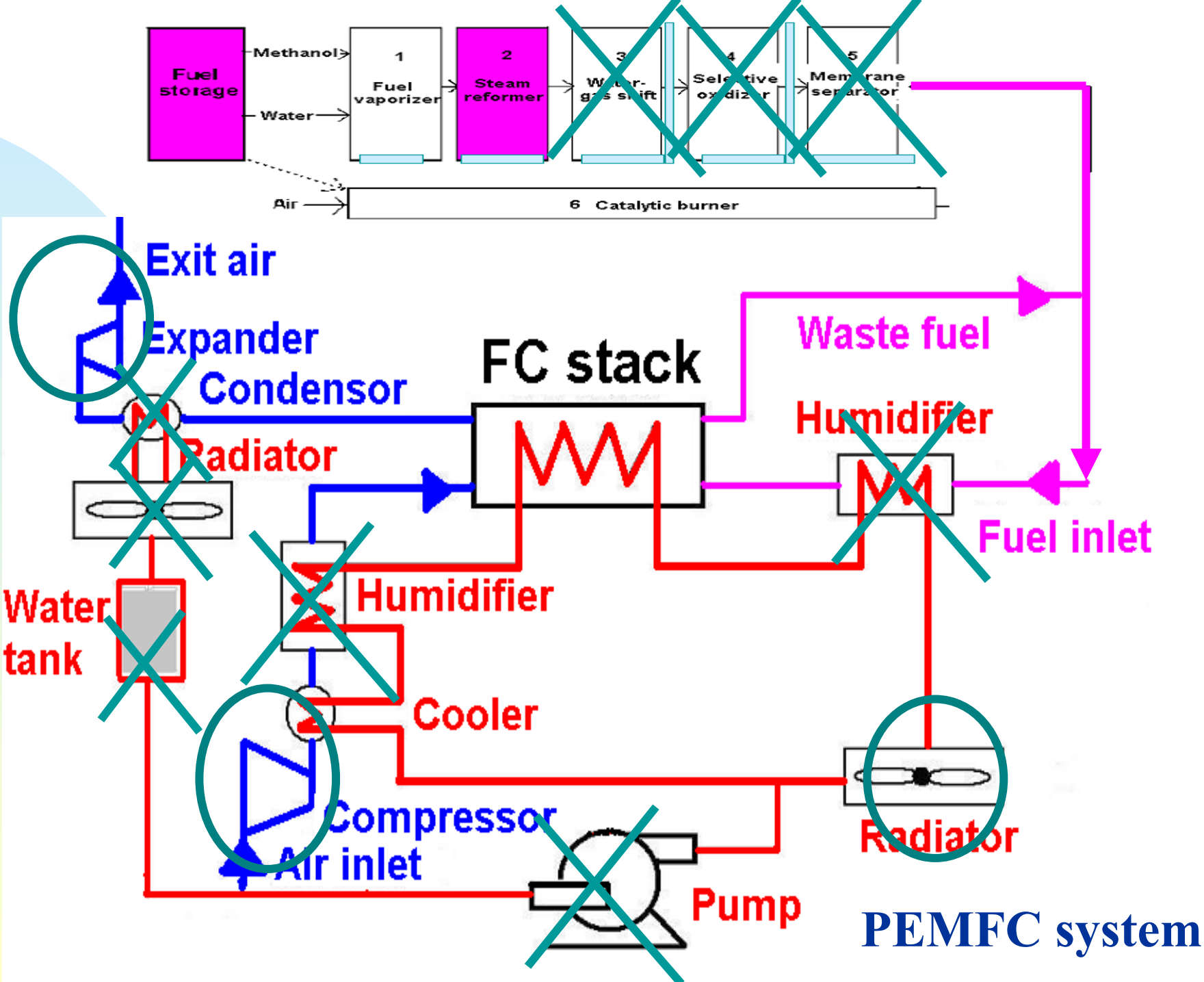




Integration test



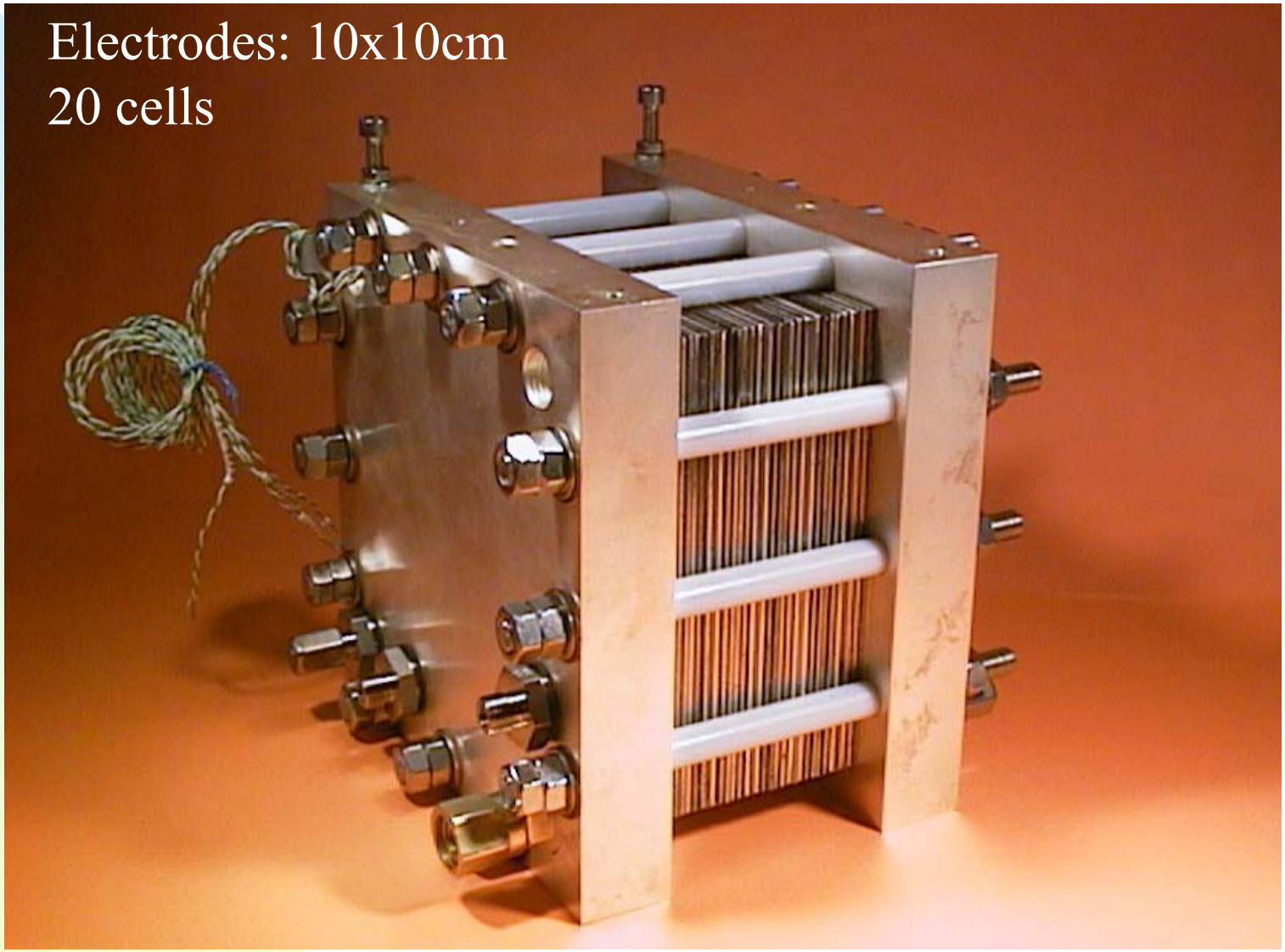




PEMFC system

Example of a high temp. PEMFC stack

- developed at Department of Chemistry Technical University of Denmark

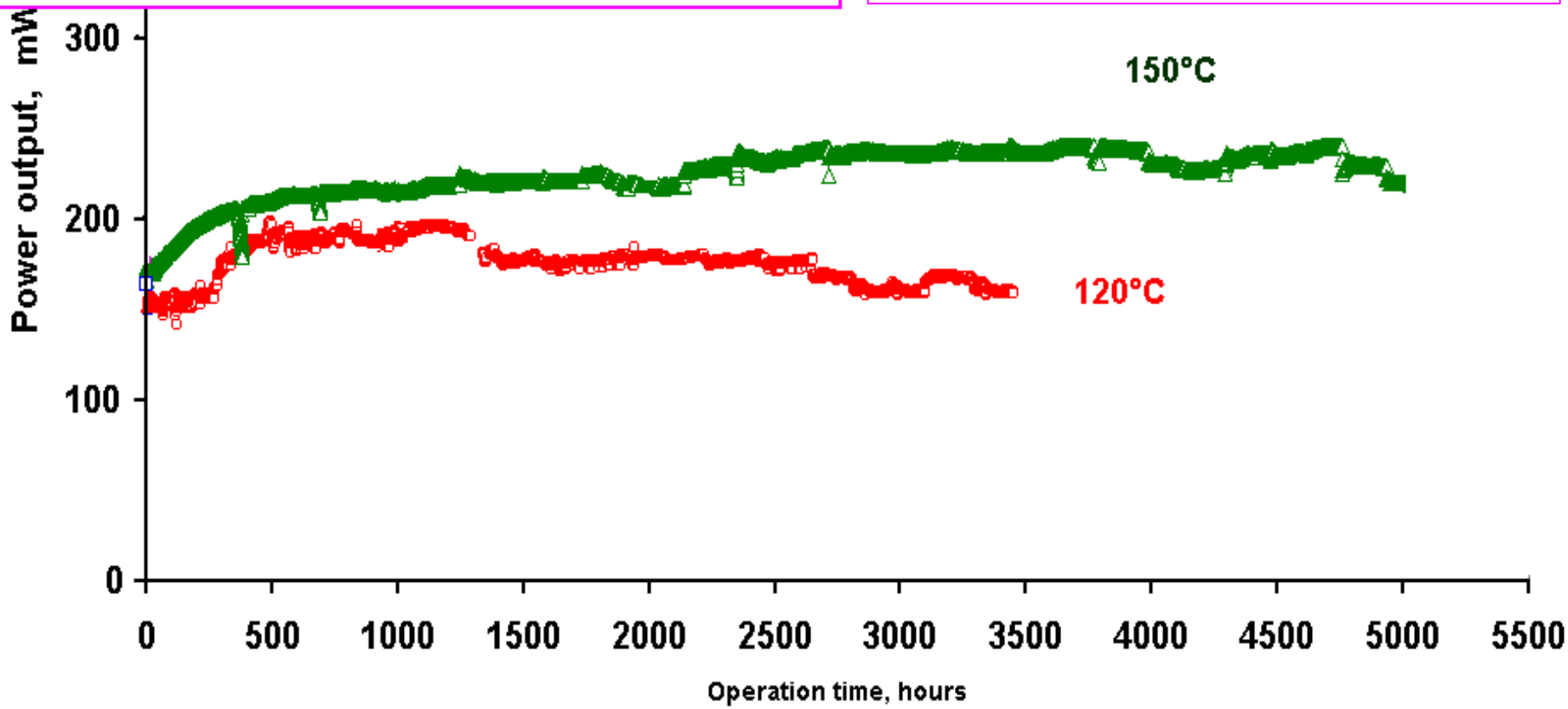


Lifetime – continuous operation

- **the 6th Framework Program**
  Lifetime targets for PEMFC system:
  - **Stationary: >30000 hours**
  - **Mobile: >5000 hours**

Electrode, 0.4-0.5 mg Pt/cm²
PBI / H_3PO_4 membrane
H_2/O_2, 1 bar/ 1 bar
Operation at constant voltage 0.5V

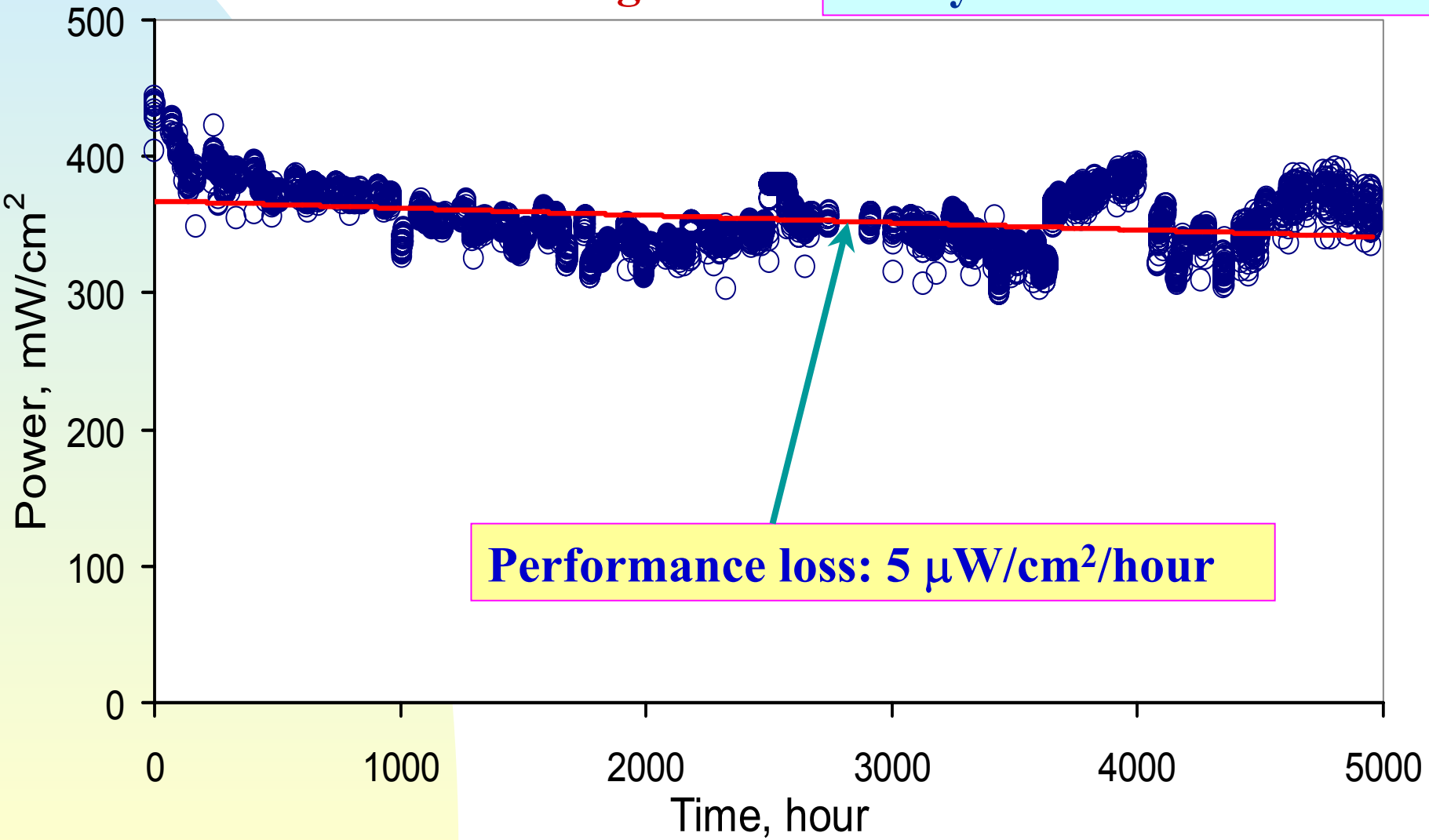
Achieved: 200°C, > 800 hours
180°C, - 1500 hours
150°C, > 5000 hours
120°C, > 3500 hours



Lifetime – thermal cycling

Switch on ca. 7 hours every working days in a period of more than 7 months – still running

Temperature: 150°C
Catalysts: 0.61 mg Pt/cm²
PBI: doping level 5.6
H_2/ O_2 1/1 bar
140 cycles in 7 months



FURIM project

under the 6th EC framework program

Further improvement of

- **Membranes operational 120-200°C**
- **Catalysts**
- **Electrodes**
- **Stack materials**

Demonstration of

- **2 kW stack**
- **integrated diesel reformer**
- **integrated afterburner**
- **feasibility for mobile and stationary applications**

13 partners from 8 countries including USA

Duration: April 2004 – March 2008